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HF ELECTRON DENSITY STUDIES UNDER PROJECT BIRDSEED

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This report describes the experiment plan, equipment and data collection and reduction procedures used in the RADC HF sounding experiment carried out under AEC Project BIRDSEED. This experiment was designed to measure the electron density produced by high altitude barium releases.

Time histories of the electron density produced by releases SAPSUCKER and TITMOUSE are presented. They are of an order of magnitude smaller in magnitude than produced by previous releases of comparable size. They alsc show a different characteristic shape.

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HF ELECTRON DENSITY STUDIES UNDER PROJECT BIRDSEED

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FOREWORD

This in-house report was prepared under ARPA Job Order No. 10570000 by personnel of Rome Air Development Center, Environmental Studies Section (OCSE). Special acknowledgment is given to Dr. Milton Peek and Dr. Donald Kerr of Los Alamos Scientific Laboratory for their help in integrating this experiment into their program. Sandia personnel at Kauai, especially Jack Canute and Ken Wiley, provided invaluable on-site assistance.

This technical report has been reviewed by the Office of Information (OI) and is releasable to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

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ABSTRACT

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I. INTRODUCTION

During May and June 1970, Los Alamos Scientific Laboratory (LASL) conducted a series of high-altitude barium releases (Project BIRDSEED from Pacific Missile Range (PMR), Kauai, Hawaii. Rome Air Development Center (RADC) participated in these tests in an attempt to measure the influence of variation in payload chemistry on the efficiency of generating barium ions in the ionosphere. The time history of electron density for each release was observed, utilizing a standard sweep frequency HF sounding technique. Unfortunately, the test objective was not fulfilled due to the presence of a blocking sporadic E layer which occurred just prior to launch on the first release (ROADRUNNER) and persisted throughout the critical observational period. The following two releases were successfully observed and indicated an overall density, an order of magnitude smaller than that of previous releases of comparable size. An interesting observation was the difference in the characteristics of electron density profiles obtained during the first two minutes after release. The second release (SAPSUCKER) showed a peak density approximately sixty seconds after release, whereas the third release (TITMOUSE) demonstrated a constant peak density for the first fifty seconds. The high-speed scan capability of the instrument provided a data point every 10 seconds which tends to eliminate the instrument as a source of the observed difference.

II. RELEASE AND POSITION INFORMATION

During Project BIRDSEED, LASL and Sandia released three high-altitude barium releases from PMR, Kauai, Hawaii. Figure 1 shows the geometry of the three releases. Releases ROADRUNNER, SAPSUCKER AND TITMOUSE took place on 15 May, 25 May and 5 June 1970 respectively. All releases were to be at a nominal altitude of 205 km. ROADRUNNER and SAPSUCKER were released approximately 50 km to the north of the launch complex while TITMOUSE was released the same nominal distance to the southwest. Table I summarizes the release parameters of the payloads. Three different chemistries were used while the payload mass and release altitude were kept constant. Although the nominal release point was different for TITMOUSE, this causes little difference in the HF measurements since the antenna in use was broad enough to cover both release points.

III. THEORETICAL FACTORS

The step-frequency ionosonde is a standard technique for measuring the electron density of the ionospheric layers. The radar pulse propagates in the ionosphere until a region is reached where the electron density is great enough to reflect the wave. Thus, in measuring the peak electron density of a barium cloud, the lack of return on a given frequency implies that there is no region in the cloud with sufficient electron density to reflect the pulse.

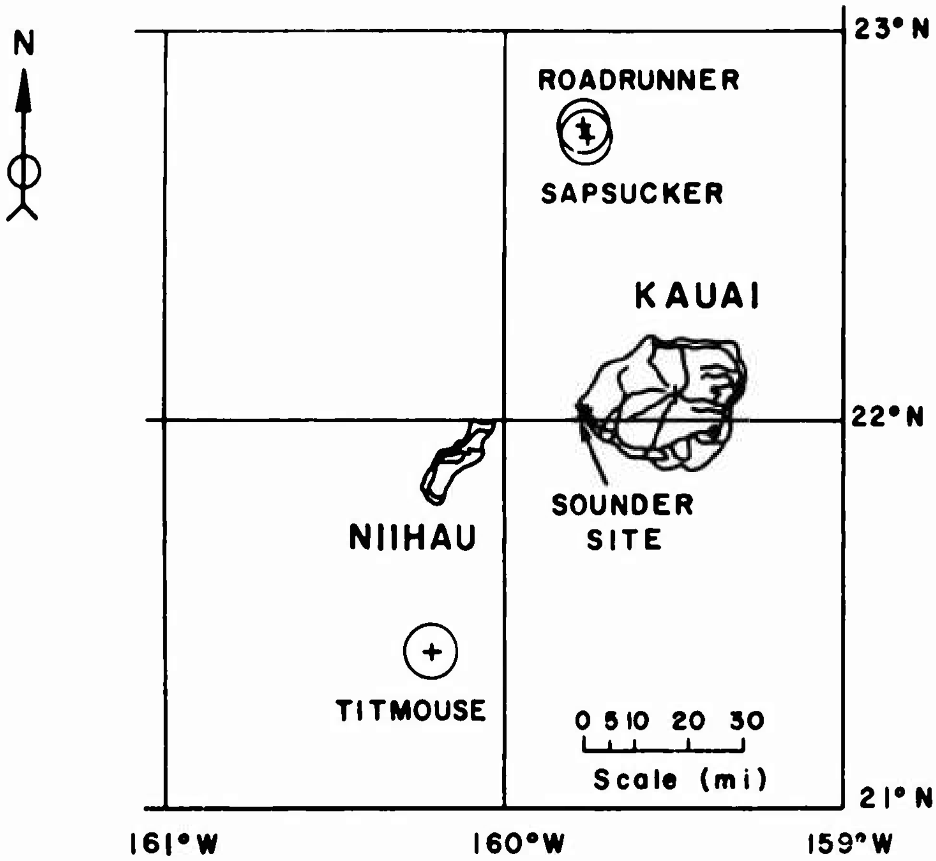

Figure 1. Experimental Geometry

The electron density required to reflect a wave of specified frequency is given by:

$$N = 1.24 \times 10^4 (F)^2 \text{ for the ordinary wave}$$

and $$N = 1.24 \times 10^4 (F^2 - FF_h) \text{ for the extraordinary wave where}$$

N = electron density (e/(cm^3))

F = operating frequency (MHz)

F_h = electron gyro frequency (MHz).

As seen from the above equations, the extraordinary wave requires less electron density to reflect it than the ordinary wave. Complete loss of sounder return means that the peak electron density is lower than required for reflection of the extraordinary wave. By taking a series of ionograms at specified intervals, the time history of the peak electron density of the barium cloud can be obtained by noting the highest frequency returned from the cloud at the given point of time.

TABLE I. RELEASE PARAMETERS

RELEASE NAME	ROADRUNNER	SAPSUCKER	TITMOUSE
Date	15 May 1970	25 May 1970	5 June 1970
Release Time (Local)	1947: 23.42	1952: 24.47	1955: 24.44
Position	22.748 N 159.75 W	22.73 N 159.74 W	21.41 N 160.23 W
Altitude (km)	234	212	207
Payload (Kg)	16	16	16
Chemistry			
Ba : CuO Ratio	1.7:1	1.7:1	2.5:1
Ba $(N_3)2$	None	1.8%	None
*S_r	0.16 Kg	0.16 Kg	0.16 Kg

*S_r replaced
0.16 Kg of barium
in all shots

Figure 2, for example, shows a typical ionogram taken after release has occurred. Trace A is the return from the barium cloud and trace B is an F layer return. The peak electron density of the cloud at this time can be calculated from the highest frequency returned in trace A.

Calculations of the total ion inventory in the cloud can be made by combining the HF measurements as described above with a densitometer analysis of the optical data taken by LASL. This analysis is now proceeding at RADC.

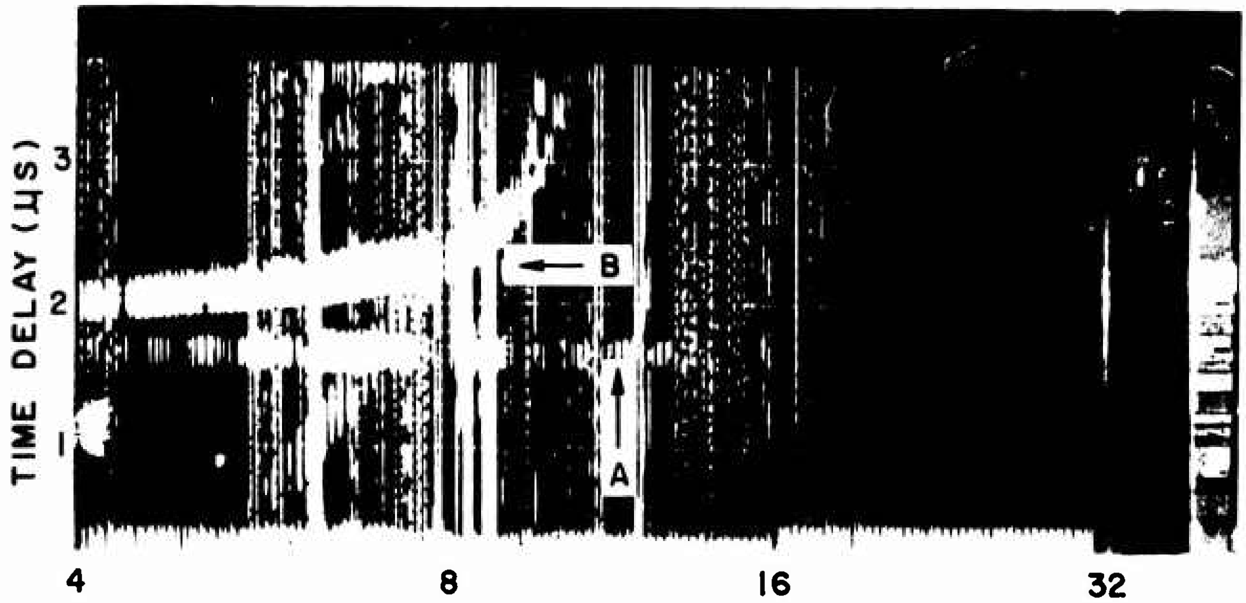

Figure 2. Ionogram - Barium Cloud Return

IV. RADC INSTRUMENTATION

The RADC experimental complex was set up in the PMR receiving building located approximately one mile south of the launch complex. Equipments used included a Granger Associates Model 902A Sounder Transceiver, a Granger Model 126A Distributed Amplifier (Figure 3) and a 32' in-house constructed delta antenna (Figure 4). The delta antenna radiates a broad upwardly directed beam of linear horizontal polarization. Dr. George Thome of Raytheon Spencer Labs ran theoretical antenna patterns showing that the half-power beamwidth would include all the angles of interest for the frequencies of interest. The Granger Sounder sequentially transmits and receives 120 frequencies spaced in the band from 4 to 32 MHZ. The operating frequencies are given in Table II. Two 200 usec pulses were transmitted per frequency at 50 pulses per second. Thus, the 120 frequencies were scanned in approximately five seconds. Peak power output was 25 kilowatts. The received signals were recorded on both 35 mm and Polaroid film in the familiar sounding format as in Figure 2. Also, pulse-to-pulse A-scan pictures were taken, using a Beattie-Colman camera.

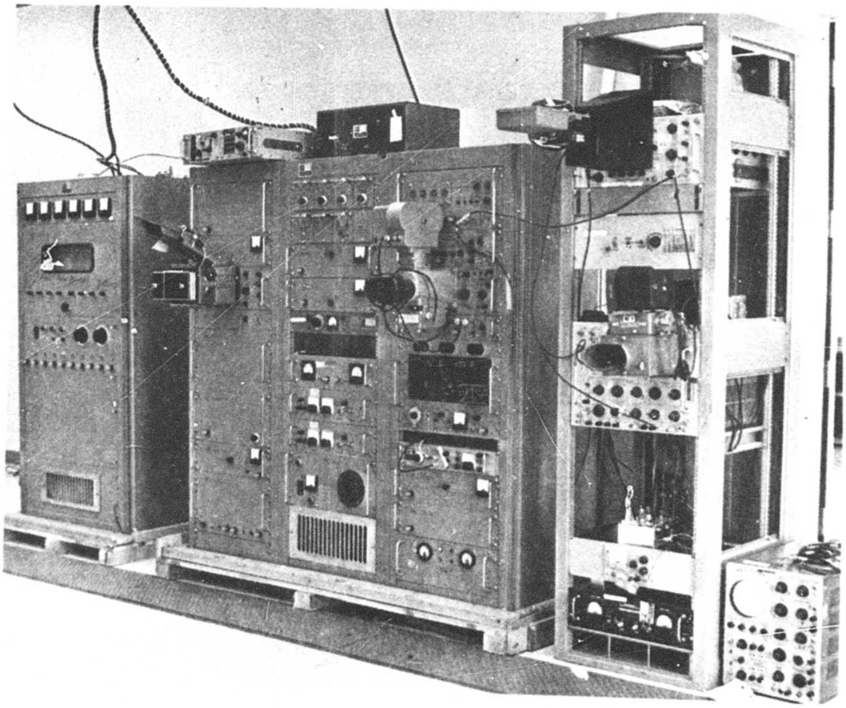

Figure 3. Granger Sounder Installation

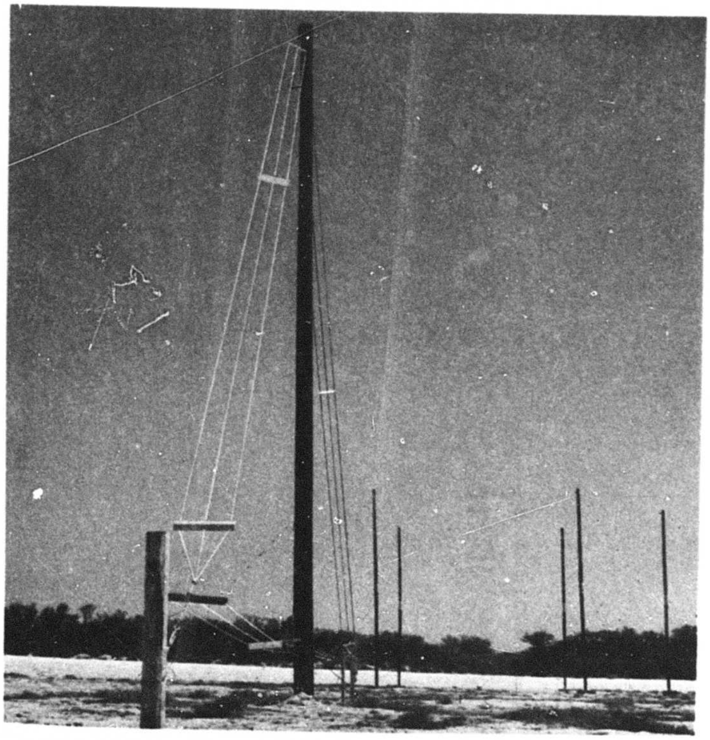

Figure 4. Delta Antenna Installation

TABLE.II. SOUNDER OPERATING FREQUENCIES

CHANNEL	BAND A	BAND B	BAND C
0	4.05	8.1	16.2
1	4.15	8.3	16.6
2	4.25	8.5	17.0
3	4.35	8.7	17.4
4	4.45	8.9	17.8
5	4.55	9.1	18.2
6	4.65	9.3	18.6
7	4.75	9.5	19.0
8	4.85	9.7	19.4
9	4.95	9.9	19.8
10	5.05	10.1	20.2
11	5.15	10.3	20.6
12	5.25	10.5	21.0
13	5.35	10.7	21.4
14	5.45	10.9	21.8
15	5.55	11.1	22.2
16	5.65	11.3	22.6
17	5.75	11.5	23.0
18	5.85	11.7	23.4
19	5.95	11.9	23.8
20	6.05	12.1	24.2
21	6.15	12.3	24.6
22	6.25	12.5	25.0
23	6.35	12.7	25.4
24	6.45	12.9	25.8
25	6.55	13.1	26.2
26	6.65	13.3	26.6
27	6.75	13.5	27.0
28	6.85	13.7	27.4
29	6.95	13.9	27.8
30	7.05	14.1	28.2
31	7.15	14.3	28.6
32	7.25	14.5	29.0
33	7.35	14.7	29.4
34	7.45	14.9	29.8
35	7.55	15.1	30.2
36	7.65	15.3	30.6
37	7.75	15.5	31.0
38	7.85	15.7	31.4
39	7.95	15.9	31.8

V. EXPERIMENTAL PROCEDURE

In forming an experimental procedure for covering the barium releases, it was noted that the ambient condition of the several ionospheric layers could have an effect on the experimental results. Because of this, the plan was to take soundings of the ionosphere several hours before and after release. Also, two round-the-clock periods of operation were envisioned along with sounding the evening before and after each release. For the ambient data, 50 usec pulses were transmitted instead of the 200 usec, and scans were taken every 10 minutes, starting at T-4 hours. At T-7 minutes, the high-speed scan was initiated, pulse width being changed to 200 usec and scans being taken every 10 seconds. At T-3 minutes, the A-scan camera was switched on. Polaroid pictures were taken every minute from T + 0 to T + 20 and then every five minutes until T + 60, At T + 20, the A-scan camera was turned off and scans were decreased to one every minute. Normal ambient operation started again at T + 60 and continued until T + 3 hours.

VI. RESULTS

The reduction of the sounder data for ROADRUNNER is complicated by the existence of returns from a sporadic E layer which appeared just before release. The fact that the F layer can be seen through the E_s suggests that the E_s is patchy and that the RF energy is penetrating through the gaps. The small extent of the barium cloud, however, made it possible for the E_s patches to block out returns from the cloud. Another complication was that the two-hop E_s return had a propagation delay the same as the barium cloud making interpretation a practical impossibility.

During SAPSUCKER and TITMOUSE, E_s as observed during ROADRUNNER, was not present. (E_s did build up after the TITMOUSE release but caused no data reduction problem.) The time histories of peak electron density during SAPSUCKER and TITMOUSE are shown in Figure 5. A peak electron density of 3×10^6 e/cm^3 was achieved for SAPSUCKER and at least 2×10^6 e/cm^3 for TITMOUSE. These densities are an order of magnitude smaller than previous releases of comparable size. Also, the time histories of the densities of these two releases are markedly different. While SAPSUCKER shows a gradual build-up of density until T + 60 seconds, TITMOUSE shows no such build-up. The electron density decay rate of TITMOUSE is also greater than SAPSUCKER. Figures 6, 7 and 8 show the ionospheric background during the periods of the ROADRUNNER, SAPSUCKER and TITMOUSE releases. Of particular interest is the strong emergence of a sporadic E layer at approximately release time. Background data taken on 4 June (Figure 9) also shows sporadic E of this nature. Future programs using HF sounding techniques of this kind should be aware of the detrimental effects such sporadic E can cause.

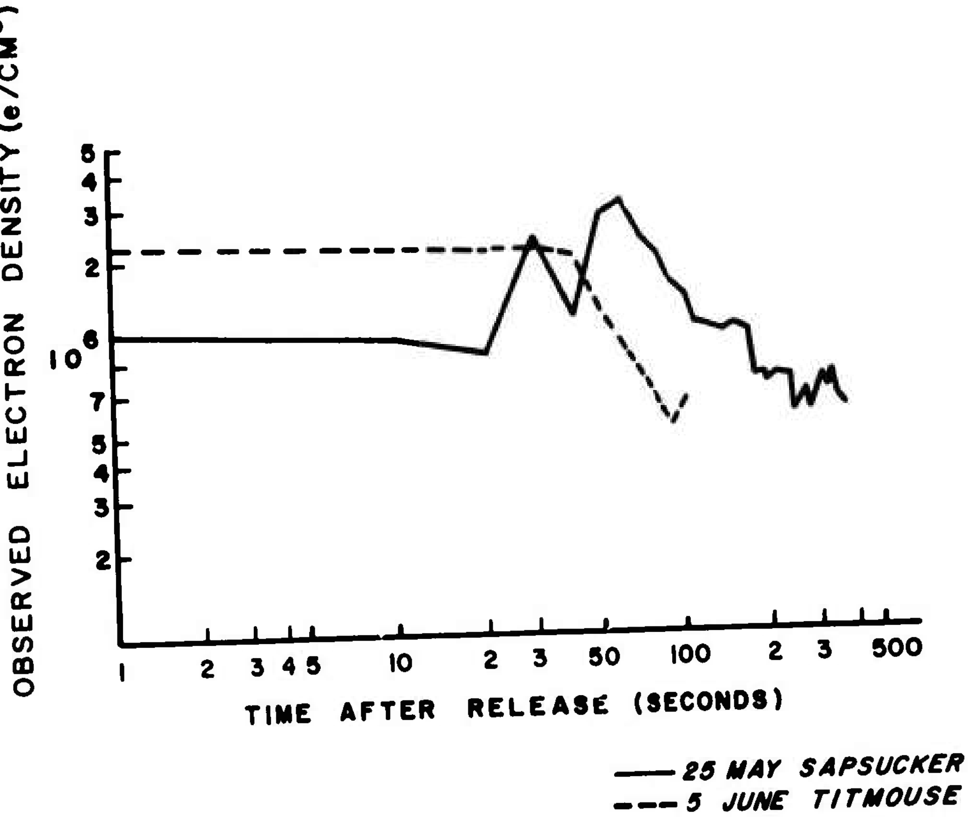

Figure 5. Observed Electron Densities - SAPSUCKER and TITMOUSE

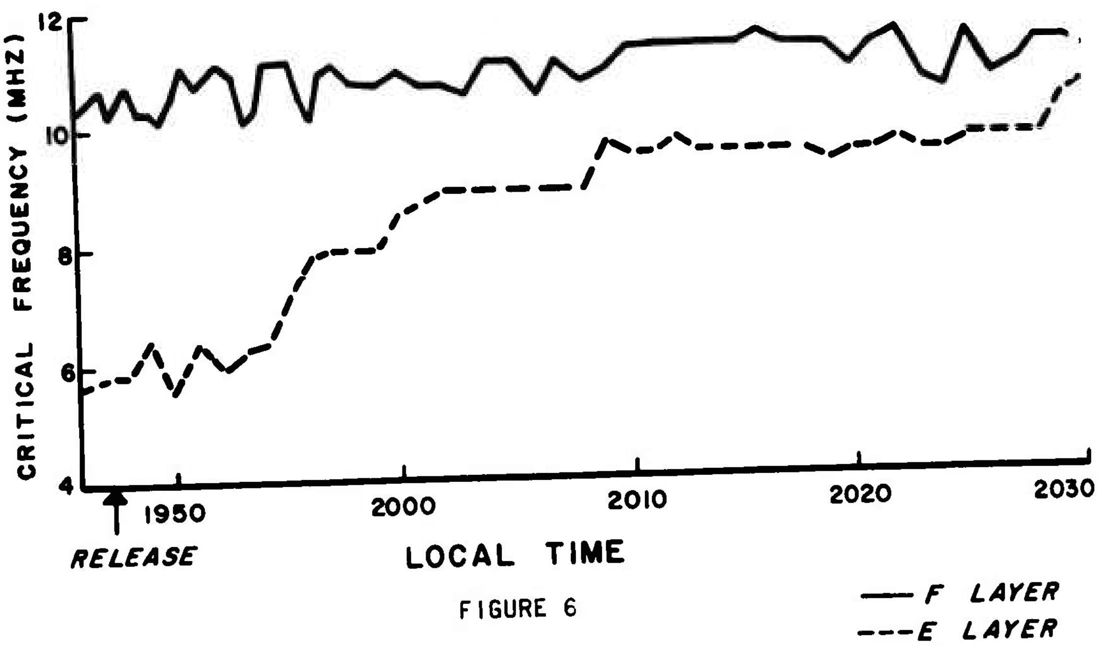

Figure 6. ROADRUNNER Ambient Ionosphere (15 May 1970)

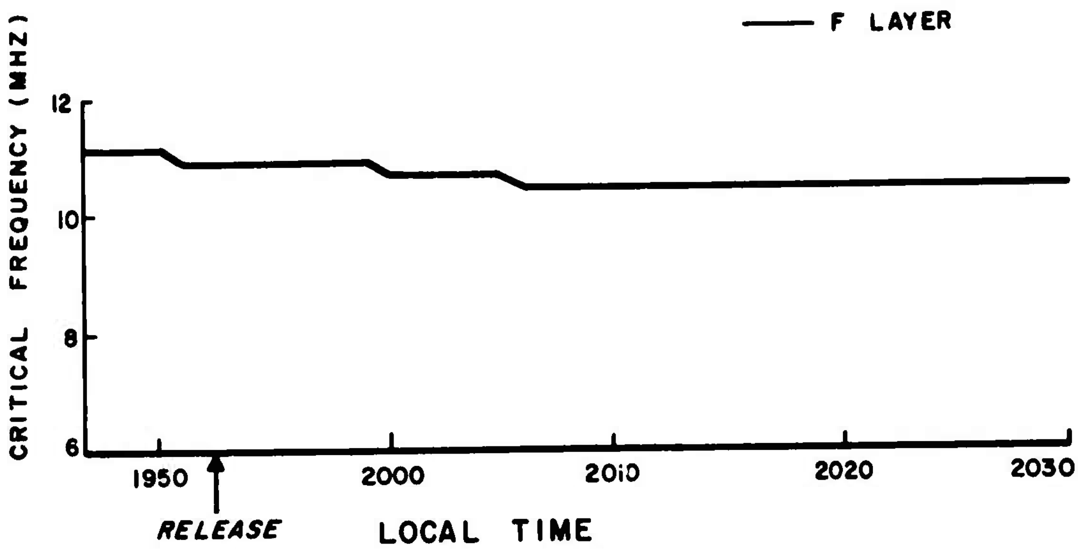

Figure 7. SAPSUCKER Ambient Ionosphere
(25 May 1970)

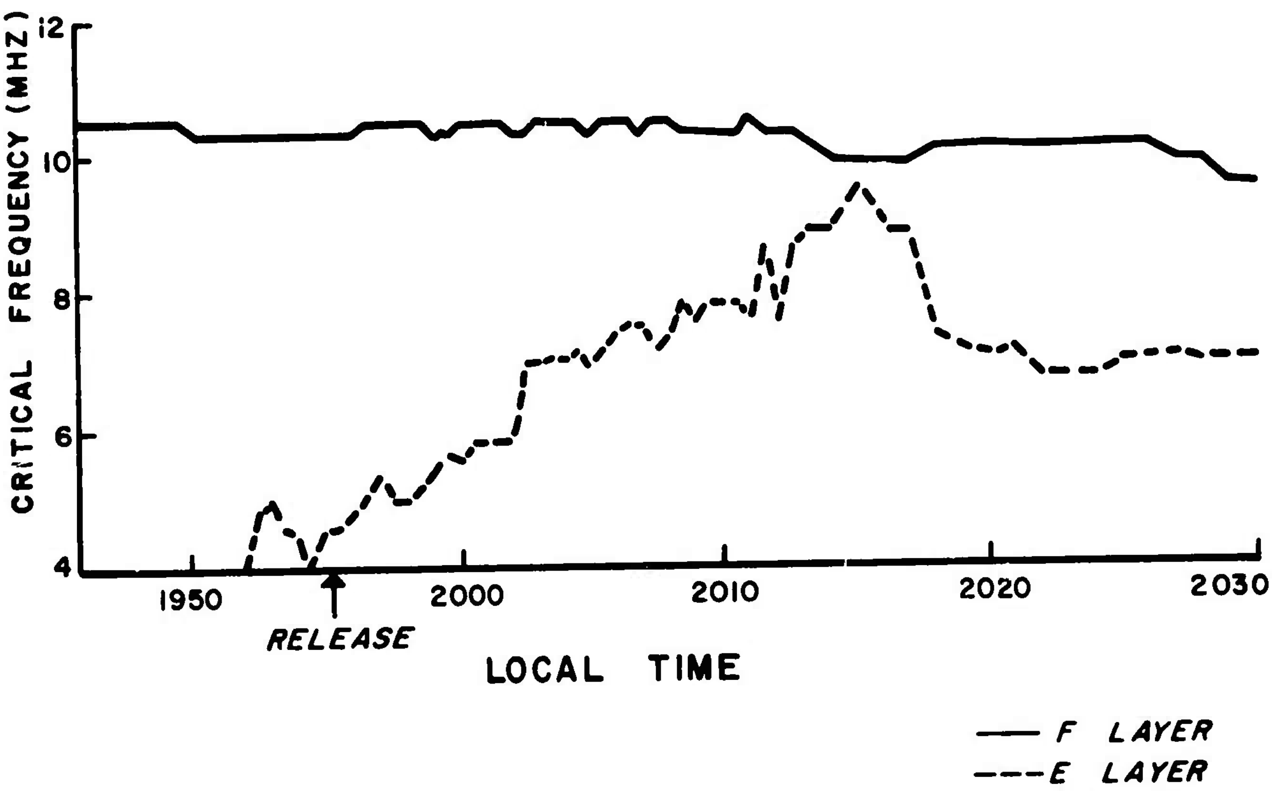

Figure 8. TITMOUSE Ambient Ionosphere
(5 June 1970)

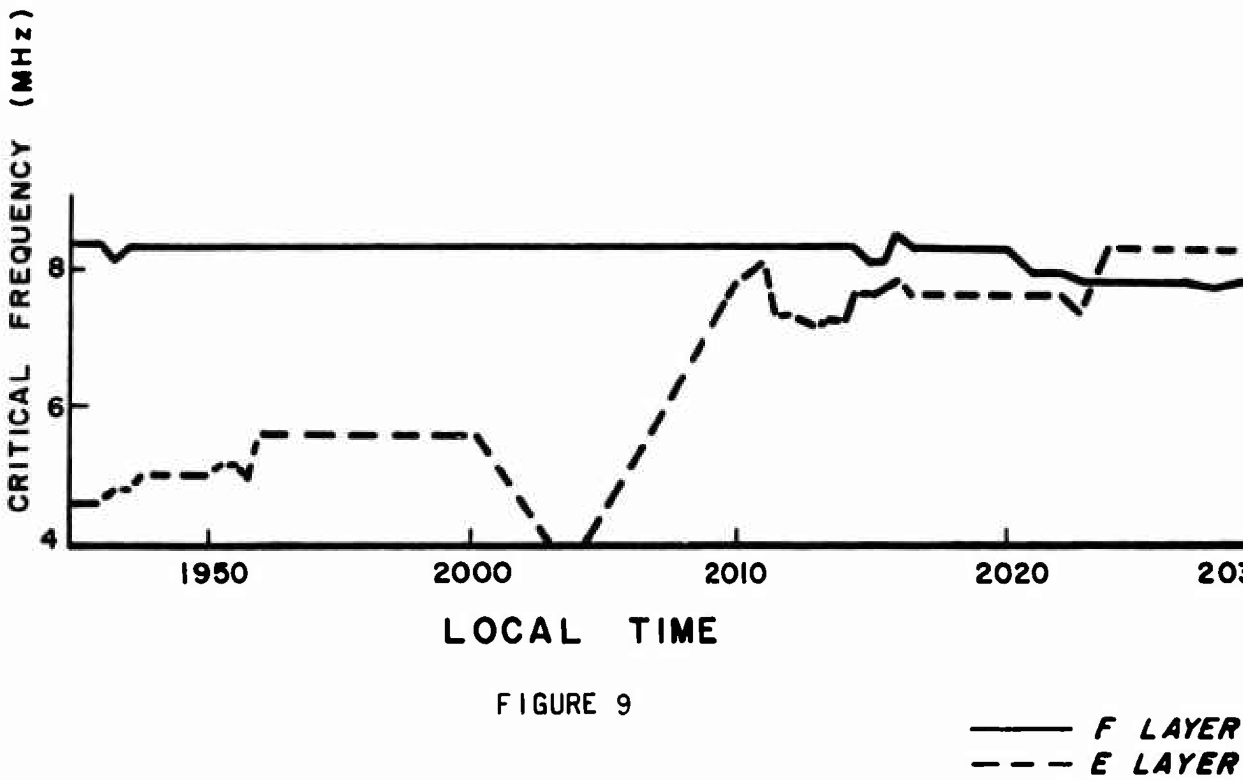

Figure 9. Ambient Ionosphere
(4 June 1970)